**SUPPLEMENTARY MATERIAL**

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# 1. ERA-GABCA initiative participants

**Organizing committee**

Débora Pires Paula, Embrapa – BR (co-chair)

David Andow, University of Minnesota – US (co-chair)

Barbara Barratt, AgResearch – NZ

Joop van Lenteren, Wageningen University – NL

Robert Pfannenstiel, USDA APHIS - US

**Expert panel** (participated at least in one out of six forums)

1) BRAZIL

* Embrapa

 Paula, Débora P. / Embrapa Genetic Resources and Biotechnology

 Capalbo, Deise M. F. / Embrapa Environment

 da Silva, Marcelo L. / Embrapa Genetic Resources and Biotechnology

 Fontes, Eliana M. G. / Embrapa Genetic Resources and Biotechnology

 Pires, Carmen S. S. / Embrapa Genetic Resources and Biotechnology

 Sujii, Edison R. / Embrapa Genetic Resources and Biotechnology

 Togni, Pedro H. B. / Universidade de Brasília (UnB)

* Ministry of Agriculture, Livestock and Supply (MAPA), Depto. de Fiscalização de Insumos Agrícolas (DFIA) - Secretaria de Defesa Agropecuária (SDA)

 da Silva, Andre F. C. P. (Director)

* Universidade Federal de Lavras (UFLA) and ESALQ

 Bueno, Vanda H. P. (Vice-President of IOBC)

* CESIS Consultancy and Training

 de Castro, Maria Luiza M. P. (Director)

 Vilella, Francys M. F. (Director)

2) ARGENTINA

* Universidad Nacional de La Plata (UNLP) and Consejo Nacional de

Investigaciones (CONICET)

* Centro de Estudios Parasitológicos y de Vectores (CEPAVE)

 Cédola, Claudia

 Luna, María Gabriela

* Ministerio de Agroindustria de la Provincia de Buenos Aires

 Rodriguez, Mônica

3) CHILE

* Pontificia Universidad Católica de Chile, Facultad de Agronomía e Ingeniería Forestal

 Zaviezo, Tania

4) USA

* University of Minnesota (UMN)

 Andow, David

 Heimpel, George (President, IOBC)

* USDA APHIS

 Pfannenstiel, Robert

* Association of Natural Biocontrol Producers (ANBP)

 LeBeck, Lynn (Executive Director)

* Kansas State University (KSU)

 Michaud, JP

 Nechols, Jim

 Ruberson, John

* Michigan State University (MSU)

 Landis, Doug

* North Dakota State University (NDSU)

 Harmon, Jason

* Texas A&M University

 Eubanks, Micky

* University of California, Davis

 Rosenheim, Jay

* University of Massachusetts Amherst (UMass Amherst)

 van Driesche, Roy

5) THE NETHERLANDS

* Wageningen University and Research (WUR)

 van Lenteren, Joop

* Netherlands Food and Consumer Product Safety Authority (NVWA), National Plant Protection Organization (NPPO)

 Loomans, Antoon

* Koppert Biological Systems

 Klapwijk, Johannette (Regulatory Affairs Specialist, Entomology)

6) DENMARK

* Aarhus University

 Lövei, Gabor

* University of Copenhagen

 Howe, Andy G.

7) UNITED KINGDOM

* Centre for Agriculture and Biosciences International (CABI)

 Schaffner, Urs (Head of Ecosystems Management)

* Centre for Ecology & Hydrology (CEH)

 Roy, Helen

8) ITALY

* Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA), Research Centre Trisaia

 Arpaia, Salvatore

9) SPAIN

* Universitat Jaume I (UJI)

 Jaques, Josep Anton

10) SWITZERLAND

* International Organisation for Biological Control (IOBC)

11) BELGIUM

* Invertebrates Biocontrol Agents, International Biocontrol Manufacturers Association (IBMA)

 van der Veken, Lieselot

 Wäckers, Felix

12) NEW ZEALAND

* AgResearch

 Barratt, Barbara (Past IOBC President)

 Gerard, Pip

* Environmental Protection Authority (EPA)

 Ehlers, Clark

* Plant and Food Research

 Todd, Jacqui

* Scion Research

 Withers, Toni

* Department of Conservation Te Papa Atawhai, Threats Unit - Biodiversity Group

 Green, Chris

13) AUSTRALIA

* Commonwealth Scientific and Industrial Research Organisation (CSIRO)

 Hayes, Keith

* Department of Agriculture and Fisheries, Biosecurity Queensland

 Day, Michael

14) JAPAN

* Center for Ecological Research, Kyoto University

 Yano, Eizi

* Laboratory of Ecological Information, Graduate School of Agriculture, Kyoto University

 Hinomoto, Norihide

# 2. Simplified ERA

A simplified ERA can be used when the exotic GABCA is known to be established in the receiving environment, a valid ERA for the exotic GABCA exists, and the proposed release is a reintroduction, but one or more of the following conditions occurs:

a) An adverse effect(s) on a known at-risk non-target species[[1]](#footnote-1) has been identified locally.

b) The source of the exotic population to be released is not from the established population or the population where it originated.

If a), i.e., an adverse effect on a non-target species has been identified in the release environment, then the simplified ERA must reassess that particular effect by:

(1) determining if the exotic GABCA is successfully reproducing on the non-target (NT) species. If so, then there is a persisting effect, and the safety and acceptability of this effect must be determined using the Screening Assessment for this potential effect, and if necessary the Definitive Assessment. If it does not successfully reproduce on the NT, then the identified adverse effect is non-persisting;

(2) determining if the exotic GABCA has any persisting adverse effects on closely related NT species in the release environment.

If all of these effects are non-persisting effects, then no further assessment is required.

If b), i.e., the origin of the proposed exotic GABCA for release is not from the established population or the original source population, then the simplified ERA must determine if the proposed exotic GABCA source has similar ecological characteristics to the population that is already established as follows:

(1) the host range/prey range and species potentially affected are the same as the established exotic GABCA, and

(2) the proposed exotic GABCA has the same reproductive characteristic as the established exotic GABCA (i.e., either sexually reproducing or parthenogenic).

If it meets these two criteria, then no further assessment is required. If it does not meet these criteria, then it cannot be assessed by a simplified ERA, and must continue with the Screening Assessment.

# 3. Summary Reports

Forums 1 to 3 and 6 will be provided upon corresponding-author request.

## Forum 4

(online discussion forum from June 17 to 30, 2019)

Theme: Risk threshold in the Screening Assessment and begin of the Definitive Assessment

Number of respondents: 23 experts, 13 provided responses about the risk threshold, 17 completed the ‘Non-target species selection’ form for the Definitive Assessment.

**Case-study material**

* Biology of *Fopius arisanus* (polyphagous parasitoid):

<https://docs.google.com/document/d/1t0Ghtn6Fc6wG2EsDyVntXtLdjlbOC4bECBso_VMFekE/edit?usp=sharing>

* Biology of *Amblyseius swirskii* (predatory mite):

<https://docs.google.com/document/d/1YOKbTLWGIt0WQlFUPuwl0NhNu4z8YdLXYMNrG1eMHjw/edit?usp=sharing>

* Experts could choose a species with which they were familiar

**Content and goals**

*1. Risk threshold to be used in the Screening Assessment*

In previous forums, experts used readily available data and conservative assumptions to estimate:

* Likelihood of Establishment (*LE*) of an exotic GABCA in a receiving environment.
* Adverse Effects (*AEi*) on non-target species by scoring the Likelihood of Encounter and Effect (*LEEi*) and the associated Degree of Harm (*DHi*) for each category *i* of potential non-target effects. Adverse effect *i* was obtained by the product of those: *AEi*= *LEEi* x *DHi*.

With *LE* and *AEi* the risk for each potential adverse effect can be estimated. Specifically, suppose there are *i* = 1, …, n categories of potential non-target effects of the exotic GABCA, so the category risk would be:

*Riski* = *LE* $x$ *AEi*

To determine which categories of risk(s) are important enough to assess further, we proposed that risks > 6 should be analyzed further in a Definitive Assessment. Why above 6? Because, for example, the Likelihood of Encounter and Effect would need to have a score higher than 2 (i.e., "unlikely" in the *LEEi* scale) or a Degree of Harm higher than 3 (i.e., "Highly adverse: widespread and large and reversible" in the *DHi* scale).

Experts were asked to examine *Riski’s* from previous Screening Assessments for 19 categories of potential adverse effects an exotic GABCA (*Fopius arisanus*, *Amblyseius swirskii* and *Harmonia axyridis*) may have on non-target species in an intended receiving environment. They were asked to critique the threshold of *Riski* > 6. In this exercise, the predatory ladybird can be considered as a positive control because it is considered to have harmful environmental effects. Specifically, experts were asked to comment if the risk threshold >6 is too high or too low or reasonable, and if it is too high or too low, provide a rationale and a different value for the threshold.

*2. Starting the Definitive Assessment tier: non-target test species selection process*

A **Definitive Assessment** is needed when the Screening Assessment determines that there are potentially significant adverse effects of an exotic GABCA. Depending on the number and complexity of these potentially significant adverse effects, an applicant may choose to terminate the process and avoid additional costs of an ERA.

The Definitive Assessment provides a final characterization of the risks of an exotic GABCA. It proceeds by:

1. Identifying and selecting non-target test species to assess for the categories with potentially significant risks,
2. Specifying a realistic mechanistic pathway(s) by which the exotic GABCA could have an adverse effect on the non-target species (these are called risk hypotheses),
3. Selecting appropriate ways to measure the effect (these are called assessment endpoints),
4. Generating estimates of establishment of the exotic GABCA, encounter between the exotic GABCA and a non-target test species, and effects on that species, and
5. Characterizing risk, which involves calculating it and then interpreting if it is acceptable or not.

This forum focuses on the first step. Here, non-target test species selection is done in the last tier of the ERA, the Definitive Assessment, and is associated with the categories of potential effects above a threshold (*Riski* >6) in the Screening Assessment. For example, if the category of potentially significant adverse effect is "*reduction of a native predator or parasitoid and/or predation or parasitism via exploitative competition*", then the non-target species to be identified for the Definitive Assessment must be ones that could compete with the exotic GABCA by consuming the same foods as the exotic GABCA.

This approach differs from previous non-target test species selection methods for biological control agents (e.g., Van Driesche and Reardon 2004; Kuhlmann et al. 2006; Todd et al. 2015), in which the potential non-target test species are listed at the beginning of the ERA, resulting in much larger number of non-target species, which are then filtered.

Experts were asked to select an exotic GABCA of their choice, identify a significant category of adverse effect, identify non-target species potentially at risk from the exotic GABCA, and score several queries related to the risk of the exotic GABCA to the non-target species. A rationale for this approach is provided at <https://docs.google.com/document/d/1sL-E1ck6ddQAWxHihsiwYGPqbZTQYTSXv8kGJiNomR4/edit?usp=sharing>.

*3. Scoping and Screening Assessment updated document*

Experts were provided an updated version of the tiered assessment method for exotic GABCAs.

**Risk threshold used in the Screening Assessment (*Riski* > 6)**

Four experts said the threshold 6 is too high. The major concern is the need for a strong precautionary approach. Consider a worst-case scenario where for all *i* categories of non-target effects of an exotic GABCA were ranked say 3 for *LEE* (Likelihood of Establishment and Effect) and 2 for *DH* (Degree of Harm). Would one really be comfortable letting this through as "low risk"? This high correlation of *LEE* and *DH* across all *i* categories suggests that the exotic GABCA has multiple types of local impacts, so the distribution of scores should also be considered in making a determination of safety. Another expert said the threshold should be 4, because any category with a *DH* of 3 or 4 must have additional investigation unless *LEE* is highly unlikely. One expert said the threshold should be 5 with a *DH* of 3 or above. This will ensure exotic GABCAs that are less well known or more subtle in their effects would go through the entire assessment process, and thus reduce the risk of introducing a harmful species.

Three experts said that the threshold should not be constant. One expert said the threshold should change for different exotic GABCAs and receiving environments, because a constant threshold detracts from the case-specificity of both clearly described risks and clearly described potential benefits. Another expert said the threshold should be different for different categories of risk. For example, if the non-target species is an endangered species, a 6 is too high. Yet another said the threshold should be different for different values of *LEE*. The current method weights the value of *LEE* and *DH* equally, and it might be better to have a different *DH* threshold for each *LEE*.

Six experts said that the threshold of 6 was reasonable, because the values of *LEE* and *DH* are conservative already and they are probably too high. One of these experts suggested that to be cautious, a threshold of 5 would also be reasonable. In contrast, a different expert suggested that the case of *LEE* =4 (likely) and *DH* =2 (Adverse: local or small or possibly reversible) might be considered safe and not investigated further.

For the next forum, we plan to provide some of these alternatives to the expert panel with more examples, so we can try to obtain more agreement on this threshold. Regarding the suggestion that the threshold should be different for each exotic GABCA and environment, we agree that the idea of case-specificity is important. However, this would require an additional step to determine the threshold in each case, which further complicates the assessment. In addition, the case specificity should be centered on a) which adverse effects are considered, and b) the scores for the effects. If a particular adverse effect is considered more important for a particular exotic GABCA, the scores should be higher.

**Non-target test species selection in the Definitive Assessment**

There were 16 completed examples of the Non-target Test Species Selection Form (Table 1). Three experts explicitly indicated reluctance to complete the form, and four others did not complete the form, but did not indicate why.

*Overall evaluations from the panel*

*“*I think it is a useful and necessary exercise.”

“I think the explicit identification of the risk assessment endpoint is very useful - risk predictions should be made in relation to observable quantities of this endpoint so that these predictions can be (in)validated and ultimately updated (in say a Bayesian fashion) with observations.”

“It would be useful to elicit explicit estimates of uncertainty. Two other alternatives have important weaknesses: providing a midpoint estimate or a worst-case estimate. A midpoint estimate underestimates risk if the true estimate is above the midpoint, and inflates the risk if the true estimate is below the midpoint; therefore it introduces an unknown bias into the assessment. It is particularly problematic when the risk is underestimated and erroneously ends up considered safe. A worst-case estimate avoids this error, but the inflated risk can create a heavier burden of proof of the safety of the exotic GABCA. The best approach is to elicit explicit estimates of uncertainty (as was done in the Screening Assessment).”

“It would be useful to clarify the kind of data that are needed to provide a score for each question. For example, E1-E4 seem like they would be based on surveys, whereas A1-A3 seem like some sort of enclosure experiment. However, the exact estimates of A1-A3 likely would be dependent on the design of the enclosure experiment. So, it needs to be clarified what is really being estimated. An average across many conditions? The "average" conditions that will be experienced?”

Some experts listed groups of species instead of species (e.g., native thrips, Lepidoptera eggs (possibly 1500 species), native aphids, predatory mirids). Can one number cover multiple species adequately? The best practice would be to select a species in that group that is considered most valuable or most at risk, and use this one species as an umbrella for the others. Alternatively, it is possible to cover all of the species by using the maximum value for all of the species in the group for each number estimated. This provides a maximum risk for the entire group, and would indicate either that some species are at significant risk or all of the species have insignificant risk. In the former case, additional risk assessment would be required to identify the risks associated with each species.

The embedded Excel equations frequently did not work. All of these have now been corrected.

*Utility of breaking down the scoring into the three separate pathways (direct effects on individuals, direct effects on populations and indirect effects on other populations) with multiple scores on each pathway:*

Disadvantages. This imposes a considerable elicitation load on the expert. Experts will typically tire and provide less and less thought into the process as they proceed through the questions. Only the most determined and motivated will give each one the same care and consideration. A smaller elicitation load that also asks experts to consider their uncertainty might provide better outcomes.

Advantages. Each of the values can be estimated empirically, which would not be possible for a single answer for the endpoint. The separate values will provide advantages when it is necessary to conduct additional experiments to estimate risks.

**Table 1.** Exotic GABCAs and non-target species considered for the ‘Test Species Selection’ in the Definitive Assessment. Red: species selected for additional testing; Green: species considered insignificantly affected by the exotic GABCA; Yellow: species that may be considered for additional testing; No color: no recommendation provided.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Exotic GABCA** | **Environment** | **Category of effect** | **NT species 1** | **NT species 2** | **NT species 3** |
| *Harmonia axyridis* (Coccinellidae) | Midwest Brazil | 2. Reduction of natural enemies via:2c. Intraguild predation | *Cycloneda sanguinea* (Coccinellidae) | *Eriopis connexa* (Coccinellidae) | *Hippodamia convergens* (Coccinellidae) |
| *Harmonia axyridis* (Coccinellidae) | Urban agriculture, fruit trees, Copenhagen | 2. Reduction of natural enemies via:2a. Exploitative competition | *Adalia bipunctata* (Coccinellidae) | *Anthocoris nemoralis* (Anthocoridae) | *Blepharidopterus angulatus* (Miridae) |
| *Harmonia axyridis* (Coccinellidae) | Europe | 2. Reduction of natural enemies via:2c. Intraguild predation | Coccinellid 1 | Coccinnelid 2 | *Adalia bipunctata* (Coccinellidae) |
| *Harmonia axyridis* (Coccinellidae) | Southern Europe | 2. Reduction of natural enemies via:2c. Intraguild predation | *Propylea quatuordecimpunctata* (Coccinellidae) | *Coccinella septempunctata* (Coccinellidae) | *Hippodamia variegata* (Coccinellidae) |
| *Harmonia axyridis* (Coccinellidae) | New Zealand | 2. Reduction of natural enemies via:2c. Intraguild predation | *Coccinella undecimpunctata* (Coccinellidae) | *Halmus chalybeus* (Coccinellidae) | *Adalia bipunctata* (Coccinellidae) |
| *Rhyzobius lophanthae* (Coccinellidae) | Central Chile | 2. Reduction of natural enemies via:2a. Exploitative competition2b. Asymmetrical competition2c. Intraguild predation | *Coccidophilus transandinus* (Coccinellidae) | *Hyperaspis sphaeridioides* (Coccinellidae) | *Aphytis chilensis* (Aphelinidae) |
| *Fopius arisanus* (Braconidae) | Brazil | 2. Reduction of natural enemies via:2c. Intraguild predation | *Doryctobracon areolatus* (Braconidae) | *Diachasmimorpha longicaudata* (Braconidae) | *Utetes anastrephae* (Bracondiae) |
| *Fopius arisanus* (Braconidae) | Northeast Brazil | 2. Reduction of natural enemies via:2c. Intraguild predation | *Fopius caudatus* (Braconidae) | *Diachasmimorpha longicaudata* (Braconidae) |  |
| *Fopius arisanus* (Braconidae) | Brazil | 2. Reduction of natural enemies via:2a. Exploitative competition | *Doryctobracon areolatus* (Braconidae) | *Diachasmimorpha longicaudata* (Braconidae) |  |
| *Trichogramma nubilale (Trichogrammatidae)* | Midwest/Northeast USA | 4. Reduction in valued species:4a. Species of conservation interest (endangered, threatened or rare endemics) | *Lycaeides melissa melissa* (Lycaenidae) | *Neonympha mitchellii mitchellii* (Nymphalidae) | *Oarisma poweshiek* (Hesperidae) |
| *Trissolcus japonicus* (Scelionidae) | New Zealand | 4. Reduction in valued species:4a. Species of conservation interest4b. Beneficial arthropods4c. Reduction in some other valued species | *Hypsithocus hudsonae* (Pentatomidae) | *Cermatulus nasalis hudsoni* (Pentatomidae) | *Oechalia schellenbergii* (Pentatomidae) |
| *Macrolophus pygmaeus* (Miridae) | New Zealand | 2. Reduction of natural enemies via:2a. Exploitative competition | Lepidoptera eggs | *Pimeleocoris viridis* (Miridae) | Endemic thrips |
| *Macrolophus pygmaeus* (Miridae) | New Zealand | 2. Reduction of natural enemies via:2a. Exploitative competition | native aphids | *Gargaphia decoris* (Tingidae) | Neuroptera larvae |
| *Amblydromalus limonicus* (Phytoseiidae) | Japan (Eastern Asian temperate region) | 2. Reduction of natural enemies3. Reduction in herbivory | native thrips | native whiteflies | native phytoseiid mites |
| *Phytoseiulus persimilis* (Phytoseiidae) | Brazil | 2. Reduction of natural enemies via:2a. Exploitative competition | *Orius insidiosus* (Anthocoridae) | *Phytoseiulus macropilis* (Phytoseiidae) | *Phytoseiulus longipes* (Phytoseiidae) |
| *Cheiracanthium mildei* (Cheiracanthiidae) | USA | 2. Reduction of natural enemies via:2c. Intraguild predation | predatory miridae | Anyphaenidae*(*wandering spiders) | Neuropteran larvae |

**Questions.** Does the long form provide any material advantage over a much simpler elicitation that asks the expert to consider all of this complexity, but then to give a single answer for the endpoint? Does splitting this complexity up (rather than allowing the expert to lump it in their mind) provide better risk assessment or management? We lose resolution by lumping complex concepts together and it is harder to tease apart the main areas of concern. Does it point to better monitoring strategies? Does it make the elicitation demonstrably more accurate or precise? Can experts provide a good rationale for their answers to these types of questions?

**Next steps.** We need to reduce the elicitation load and elicit uncertainty. Experts provided good justifications for questions E1-E5 and A1-A3, but not for B1-B3 or C1-C3, so we need to focus on improvising B1-B3 (direct population level effects) and C1-C3 (indirect population effects).

*LIKELIHOOD of ENCOUNTER (*LEnj*) (E1-E5 scores between 0 and 1)*

Overall, there were only 2 concerns about the scores for E1-E5. Most experts provided well-reasoned justifications for their scores. The concerns were:

* E4 seems to be very similar to E3. Usually the habitats are created by the plant species, whether the plants are crops or natives.
* How can E5 be scored? It's meaning is unclear. Is it a point estimate of each encounter or a lifetime estimate for the NT? For some species with strong crypsis or defenses, it would be easy to say they would have low encounters, but in most cases how would you know that? Moreover, wouldn't this number be highly dependent on the density, experience, and condition of NT and exotic GABCA?

**Next steps.** These points need to be clarified. We will send revisions to the experts who expressed these concerns. We need to develop additional material to address how these could be estimated.

*LIKELIHOOD (*LDPj*) of a DIRECT EFFECT on INDIVIDUALS of NON-TARGET SPECIES j A1-A3 scores between 0 and 1)*

Overall, there were only 2 concerns about the scores for A1-A3. Many experts provided well-reasoned justifications for their scores. The concerns were:

* Need to rephrase A1-A3 to clarify how to use these for exploitative competition.
* How can A2 and A3 be estimated without experimentally testing the species?
* Two experts considered intraguild predation between *Fopius arisanus* and other tephritid parasitoids. When they got to these questions (A1-A3), they indicated that direct intraguild interactions (stinging another parasitoid’s eggs or larvae inside a host) were either not possible or highly unlikely, and therefore the risk was insignificant. In this case, the Screening Assessment should have indicated that the risk via intraguild predation was insignificant, and this category of risk should not have been considered in a Definitive Assessment. This result found by these experts identified and corrected a mistake in the original Screening Assessment, showing that this tiered assessment process was able to self-correct.

**Next steps.** These points need to be clarified. We need to develop additional material to address how these could be estimated.

*VALUATION (*V*) of individual effects*

Of the three cases that considered the valuation of individual effects on endangered or endemic species, the population size could be estimated roughly for the endangered species, but not for the endemic species. For endangered species, some population data must be collected to substantiate the listing as endangered. Endemic species do not have this level of information available.

**Next steps.** A different method for valuation of highly endemic species must be developed. As possible factors, we will consider existing geographic range, degree of threat to the habitat, and presence/lack of suitable food. The value of the species would be higher if it is under greater threat of loss.

*LIKELIHOOD and LOCAL MAGNITUDE on a POPULATION of NON-TARGET SPECIES j (*B1a-B3b *scores between 0 and 1)*

No one commented on the validity of the threshold of *EffDIj* < 0.001 (<0.1% of the individuals in a population expected to be killed by the exotic GABCA), to stop scoring the parameters for the direct and indirect population effects, because they would all be insignificant risks. Nine experts had at least 1 NT species with *EffDIj* < 0.001, and seven terminated the assessment for those species. Two experts did not stop at that point, but they did not consider such species for additional assessment. Therefore, it seems that the threshold was appropriate.

Overall, there were several concerns about the scores for B1a-B3b. Only some of the experts provided well-reasoned justifications for their scores. Some NT species were scored using multiple methods, even though only one was requested.

**B1a-B1b.** Use existing experimental data to score the likelihood that the exotic GABCA would affect the non-target population size. Data for this often does not exist. Fifteen NT species were scored with this method.

**B2a-B2b.** Use data from taxonomically and ecologically similar hosts/prey of the exotic GABCA. Data for this generally does not exist. Not sure if B2b was supposed to be proportion reduction, or proportion remaining? It should be the proportional reduction. Nine NT species were scored with this method.

**B3a-B3b.** Use data from taxonomically similar species to the non-target species. At what taxonomic level are data from 'surrogate species' relevant? In weed BC, it is usually only accepted if surrogate species are at least congeners. For BCA’s, host range can be very different between biotypes of the same species. Seven NT species were scored with this method.

**Next steps.** We need to clarify this section and explicitly address how it could be answered when there are no data.

*Considering INDIRECT EFFECTS*

Overall, this section was difficult for several experts to understand. Very few experts provided justifications for their scores.

**C1.** Likelihood that NT species has a key ecosystem function with another species (relative contribution of the NT species to the function). “It is unclear what is "another species"; the examples suggest that the NT is performing the ecosystem function for another species, e.g. pollination - a pollinator (NT) pollinating a flower (another species). It becomes unclear when “another species” is mentioned multiple times. And do any of these "species" refer to the exotic GABCA? In addition, this score may be very specific to a particular crop or ecosystem and have limited generality.” Twenty-six species were scored with this method.

**C2.** Likelihood of an indirect effect scored by the strength of trophic links. “Needs more explanation to clarify text. Perhaps this could be accompanied by some visuals to help aid comprehension. While these concepts are difficult to put into words, the "to that other species" is confusing. Does it still refer to the NT or other NTs not directly under assessment, which could be involved in the referred trophic links? Does it mean all the links to the other species (e.g., the pest species) or the links to the other species that the NT feeds on? If the latter, there are at least 20 other species and some of those are also pests, so would they also be key ecosystem functions?”

“Scored 1 here because the default "record 1 if unavailable" gives me that option. Obviously, we need to score something for the sum of the strengths of the trophic links for C2 to work, however, it is not clear which is the referred species.”

Fourteen species were scored with this method.

**C3.** Likelihood of an indirect effect using a surrogate method involving biomass and the number of trophic links. This received no comments; however, it was used rarely. Three species were scored with this method, but all three were also scored with method C1. Perhaps this method should be eliminated.

**MIPj.** Magnitude of the indirect effect. “It is not clear which is the indirectly affected population, the NT population or a population affected by the NT population? Also, when it is difficult to estimate how much the non-target population might change, it is not possible to estimate how much the ecosystem function might be affected.”

**Next steps.** We need to clarify this section by providing examples and simplifying the language. We also need to explicitly address how it could be answered when there are no data.

*VALUATION (V) of population effects*

Nearly all experts had problems using the valuation section.

* “It is difficult to determine the value of rare alpine endemic species to specific ecosystem services because they have not been studied enough to determine the services that they may have. In cases with rare endemics, most will not contribute significantly to any ecosystem service because they are rare, and their value is primarily as endemics with biodiversity, cultural, symbolic and/or aesthetic value.”
* “What is meant by "values identified by a human agent"? All of the listed ones are anthropocentric values, and the identified values are a subset of the list. The subset is identified by people (not the expert), who have indicated the value of the NT species.” Most of the experts appeared to identify the subset of values based on their expert knowledge of the system rather than using external valuations.

Most experts did not associate their valuation scores with their estimates of the overall direct and direct population effects. Often NT species had the same valuation score when their estimated overall population effects were several orders of magnitude different. It seems that the valuation scores were given based on the perceived importance of the species to the considered value.

**Next steps.** We will revise this section and provide examples for experts to judge. We need to clarify how the values are identified. We can refer back to the Screening Assessment for this. We need to divide the valuation process into two components: first, there is the perceived importance of the species to the value that is considered, and second, there is the relation between the estimated effects to assess how much value is actually at risk. This will need to be developed in the next forum.

**References cited**

Kuhlmann, U., Schaffner, U., & Mason, P.G. 2006. Selection of non-target species for host specificity testing of entomophagous biological control agents. In Second International Symposium on Biological Control of Arthropods, Davos, Switzerland. United States Department of Agriculture, Forest Service, Morgantown, West Virginia, USA, FHTET-2005-08, pp. 566-583.

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Van Driesche, R.G., & Reardon, R. 2004. Assessing host ranges for parasitoids and predators used for classical biological control: A guide to best practice. Forest Health Technology Enterprise Team, USDA-Forest Service. Morgantown, West Virginia, USA.

## Forum 5

(online discussion forum from September 16 to 30, 2019)

Theme: Surrogate species

Number of respondents: 29 experts

**Content:**

1. Invitation to: ICE 2020, ESA Symposium and Workshop

2. Non-target **surrogate species**: defining ecological characteristics

3. **Population effects**: data requirement

4. **Indirect effects on ecosystem services**: establishing methods

5. Reevaluation of the **risk threshold** in the Screening Assessment

**Surrogate species**

**Do you agree that surrogate species can be used to evaluate NT effects of an exotic GABCA? Why or why not? (27 answers)**

Yes, unconditionally (6 experts). Three reasons were given for agreement:

1. using surrogates is necessary because it is not always possible to test the actual NT species, and something is better than nothing;
2. by the time an exotic GABCA reaches the definitive assessment, it should be one of the better options for pest control, and surrogates may be the only way to assess some risks;
3. as there are advantages to using surrogates in biodiversity conservation, it should be used for exotic GABCAs as well.

Yes, conditionally (18 experts). There were six conditions suggested:

1. surrogate must be taxonomically and ecologically/functionally similar to the NT species (more on this in the next question);
2. surrogates could be appropriate for evaluating risks to species of conservation concern;
3. surrogates could be appropriate when assessing potential risks in the native range of the exotic GABCA;
4. surrogates should be restricted only to well-studied taxa;
5. surrogates should be restricted to cases where it is very difficult or impossible to test the actual NT;
6. more than one surrogate should be used;
7. surrogates should be restricted to estimating attack rates;

No, unconditionally (3 experts). Two reasons were given for disagreement:

1. species have unique characteristics that make it impossible to match a surrogate and risks will depend on these details;
2. characteristics that enable a surrogate to be used to evaluate risks may be associated with characteristics that make it have a lower risk, and this cannot be known.

**Are there other taxonomic or ecological characteristics that must be used to identify suitable surrogate species? (25 answers, numbers in parentheses are number of times a characteristic was mentioned)**

No additional characteristics needed (3 experts). Ecologically similar habitat, similar climate, and reliable taxonomy are sufficient.

Additional taxonomic conditions (5 experts). Restrict to the same genus or tribe (3); restrict to the same family (1); taxonomic affinity is less important than ecological similarity (1).

Additional ecological conditions (21 experts). Surrogate should be feasible to monitor and sensitive to changes caused by the exotic GABCA, and should be relevant to the ecosystem service it is representing (2). Should consider climate matching under climate change.

Specific suggestions for ecological similarity were:

* Feeding niche (number and identity of hosts/prey, feeding habit (e.g., external leaf feeder or stem borer, etc.), feeding location, feeding time of day, gregarious/solitary feeder) (7).
* Phenology (e.g., timing of occurrence of vulnerable stages) (5).
* Life history (diapause/aestivation, reproductive timing and capacity) (5).
* Voltinism (3).
* Defensive characteristics (toxicity, aggression to natural enemies, etc.) (5).
* Rate of population growth and degree of density dependence (3).
* Morphology (cryptic coloration, external morphology (e.g., hairs)) (2).
* Movement behavior (e.g., for mate finding) (2).
* Other characteristics mentioned only once: excrement handling behavior, odor, size, associated microbiome, physiology, reproductive genetics and behavior, acceptability for consumption by the exotic GABCA.

**Population Effects**

We propose an approach that is derived from population dynamics theory, using per capita reproduction and either density-independent (DI) or density-dependent (DD) mortality effects of the exotic GABCA on the NT.

**Do you agree with this approach? (26 answers)**

Yes (15 experts). Two experts commented that it will be a challenge to estimate DI or DD mortality on the NT.

Maybe (9 experts). Five reservations were provided:

1. “this may overly complicate the assessment by introducing additional uncertainty that does not help; “
2. “this relies on an extensive population dynamics database (2);”
3. “the approach may not work for species of conservation concern (although this may be moot, as these risks will be assessed elsewhere);”
4. “would be reasonable only if no other information was available;”
5. “three technical points that additional parameters might need to be included.”

No (2 experts). Two contrasting reasons were given: a) too complex for most cases, b) overly-simplified, as should consider all mortalities, not just DI and DD ones.

**Is there a better or more practical alternative? (13 answers)**

* Expert judgement, based on available literature.
* Use all available data (2).
* Retrospective testing of closely related surrogates for an exotic GABCA already released.
* Some behavioral parameters could be equally or more useful, e.g., minimum prey density threshold.
* Life table analysis and Bayesian belief modelling.
* Approach is ok for classical BC, but not for augmentative BC.

**Are the parameters the only ones needed/what else is needed? (20 answers)**

The following additions were suggested:

* Distinguish between additional vs. replacement mortality on the NT.
* Feeding niche, population fluctuations and population size of NT prior to introduction of exotic GABCA.
* Population projection matrix (separate DD mortality between immature and adult phases, and estimate intrinsic rate of increase, generation time, natural mortality rate, key mortality factors before the exotic GABCA is released).
* Knowledge of the major interactions of the NT with other species in the environment.
* Relative dispersal capacity and distance between the target and NT species can moderate/accentuate the effects of DI and DD mortality caused by the exotic GABCA.
* More detailed life table parameters and food searching and handling time (functional response parameters).
* Aggregation response, functional and numerical response, reproductive value.
* If the effect involves competition for resources, rmax (maximum intrinsic population growth rate), half saturation constant, existing population density will be useful.
* If an impact is likely, assess the overlap of the fundamental niches of the exotic GABCA and the NT.
* Emigration and immigration rates, carrying capacity, predation rates and competitive effects.
* rmax before and after introduction of exotic GABCA.
* Effect of physical factors (e.g., temperature).

**Are any of the parameters superfluous, and if so, which ones? (13 answers)**

None are superfluous (9 experts).

Three comments on the approach:

* Quantitatively, the parameters extrapolate beyond their predictive capacity.
* Although they are not superfluous, they should be estimated together and not independently.
* Estimate DI mortality first, and determine how much is additional or replacement mortality, and then determine if DD mortality needs to be assessed.

**Indirect Effects on Ecosystem Services**

We suggest the following four principles for estimating indirect effects on a key ecosystem service:

1. Indirect effects can occur via two different pathways.
2. The strength of the indirect effect is the product of the strength of the direct effects that lead to it.
3. A strong indirect effect can occur when the direct effect on the NT is weak and the NT has a very large effect on the ecosystem service.
4. The significance of an indirect effect of an exotic GABCA on an ecosystem service is reduced by the other species that contribute to the ecosystem service.

**Do you agree with these principles? Why or why not? (26 answers)**

Yes (14 experts). Three experts agreed in principle, but thought that the principles would be difficult to implement.

Partially (10 experts). The following concerns were expressed about each of the principles:

General concerns: May be difficult to obtain enough information on the interaction networks of the relevant species to implement these principles, and may be applicable only to classical biological control.

1. Not all effects can be modeled as linear ones. Need to include non-linear diagrams (e.g., apparent competition).
2. Using a simple product (i.e., *a* x *b*) may not correctly indicate the size of the indirect effect. For example, suppose a NT is the only pollinator of plant A, so its contribution is the maximum ES (let's say this is represented by the value 10), but the exotic GABCA is only expect to attack a small proportion of the population (say, 0.2), then the product is 0.2 x 10 = 2. Would that appropriately indicate the indirect risk of this interaction on the plant species' population?
3. Although theoretically possible, might be unlikely in practice or difficult to anticipate.
4. There will be interactions with the other species that are providing the ES, and these interactions will make the calculation more complicated (2).

No (2 experts). Two concerns were expressed. a) these principles ignore the effects of feedback cycles. Qualitative modeling, formulated by Richard Levins, should be considered; b) these are not useful because they require full understanding of all of the species contributing to the ES.

**If you do not agree, what would you change or delete? If you agree, would you improve or add to these principles? (16 answers)**

Six general comments were provided:

* The approach is too general to be helpful.
* Very unlikely to be useful for augmentative BC.
* Need to also consider the value of the ES overall. Concern for a low-value ES might be less than for a high-value ES.
* Maybe could use trophic networks, although this would be quite costly.
* Try to measure the change in function intensity instead of this “follow the ES provider” approach.
* Seems to be assuming that the effect of the exotic GABCA is only negative. Should make the diagrams so that they reflect both positive and negative outcomes.

Two suggestions for improving principle #1 were suggested:

* Add non-linear (tri-quadr-angular) pathways or relationships (e.g., apparent competition).
* Link these to the signed digraphs of qualitative modeling and community interaction matrices.

Four suggestions for improving principle #4 were suggested:

* Need to consider to what extent the other ES species compensate the loss associated with the NT species.
* If the NT reduction causes the ES to be concentrated in one or a few species, it may be less stable or resilient. Including some estimate of ES stability might be interesting.
* Maybe it would be sufficient to mention that there may be interactions with other species that creates uncertainty about the estimated effect. Even if such interactions were to occur, it will be difficult to attribute the effect on the ES to an indirect effect of the exotic GABCA.
* Because the NT could affect other species that affect the ES, these indirect effects should also be mentioned.

**Risk Threshold in the Screening Assessment**

We reported that the following ideas were proposed in forum 4 and requested that you recommend a threshold after considering these options and examining some case studies.

1. >6 is too high.
2. >6 is reasonable.
3. >6 is too low.
4. Should be ≥ 5 with a Magnitude of Effect (MEf) ≥ 3.
5. Should be ≥ 4.
6. Should be ≥ 3 for valued species and ≥ 5 otherwise.
7. Should not be constant, but change for different exotic GABCAs and receiving environments.

**What is your recommended threshold? (29 answers)**

22 experts thought the >6 threshold was too low, and 7 experts thought it was appropriate.

There was no consensus for a specific threshold less than that of >6, although the modal response was >5 (see table below). Several experts mentioned that a Likelihood of Effect (LEf) = 4 should trigger additional assessment no matter the value of Magnitude of Effect (MEf). One expert mentioned that the threshold used for BC of weeds would be ≥3. Three experts suggested that the threshold should not be constant.

An interesting proposal that may cover several of the concerns expressed by all of the experts was to have a variable threshold with ≥4 for valued species (endangered and rare endemics), ≥5 for other native species, >6 for exotic species, and a process in each assessment to consider if the thresholds need to be adjusted on a case-by-case manner.

|  |  |
| --- | --- |
| Threshold | # experts |
| >5 | 7 |
| ≥5 with a MEf ≥ 3 | 2 |
| ≥4 when LEf ≥ 4, otherwise R≥5 | 1 |
| ≥3 for valued species and ≥ 5 otherwise | 3 |
| ≥4 | 2 |
| ≥3 | 2 |

1. *At-risk non-target species* are those that might be adversely affected by the exotic species. They are usually selected based on knowledge from host/prey range tests and/or host/prey records extracted from the literature using criteria such as: phylogenetic, ecological, biological and socio-economic (Sands and Van Driesche 2004, https://bugwoodcloud.org/bugwoodwiki/Ch3.pdf; Kuhlmann et al. 2006, https://www.cabdirect.org/cabdirect/abstract/20073080111; Barratt et al. 2016, https://doi.org/10.1016/j.biocontrol.2015.11.012). [↑](#footnote-ref-1)